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A Method for Assessing Shoreline Stability of Alpine Lake, West Virginia

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Abstract: Rapid stability assessments are tools commonly applied to stream reaches to evaluate potential for instability and are often used to prioritize management strategies. In this work, a rapid stability assessment was created to evaluate the stability of the shoreline of Alpine Lake in West Virginia, USA. First, the assessment tool was created considering the metrics of bank height, bank angle, erosion, armoring, wind and wave action, unconsolidated materials, protection measures, vegetation, and accretion. The resulting tool was applied to 83 reaches (20-100 m in length) of the lake shoreline. The reaches were rated in terms of potential instability: very low (14%), low (42%), moderate (33%), high (10%), and very high (1%). Second, erosion rates were monitored at eight locations using erosion pins. Average erosion rates up to 0.22 mm/d were observed. Measured erosion rates generally supported the rapid assessment results, but there were some exceptions. Additional categories that consider human activity along the lakeshore for recreation should be added. If used without continued erosion monitoring, the rapid assessment should be completed multiple times because the stability of the banks with little vegetation buffer varied by season. Lastly, reclamation strategies are discussed.

Keywords: *rapid stability assessment, erosion, lakeshore*

Rapid geomorphic assessments are common tools used to characterize stream reaches and evaluate the sensitivity of channels to disturbance. Many rapid assessment tools exist for the riverine environment (e.g., channel instability index: Simon and Downs 1995; bank erosion hazard index: Rosgen 2001; Oklahoma Ozark streambank erosion potential index: Heeren et al. 2012). The metrics utilized vary by assessment tool, but most follow the same basic methods. The river of interest is divided into reaches with similar morphological characteristics. Each reach is then evaluated using metrics defined in the tool through field work, observation, analysis of climate or hydrologic data, and/or GIS methods (e.g., Simon and Downs 1995; Rinaldi et al. 2013).

Simon and Downs (1995) developed an approach to assess the potential for channel instabilities referred to as the channel instability index. The variables considered in the index include bed material, bed protection, stage of channel evolution, percent of channel constriction, number of piers in channel, percent blockage, bank erosion, meander impact, pier skew, mass wasting, high-flow angle of approach, and percent woody vegetative cover. Each variable is evaluated and assigned a score; high aggregate scores ($\geq$ 20) identify highly unstable stream reaches. It was originally developed to evaluate the potential for bridge scour and related channel instabilities but can be applied to additional disturbance areas by modifying the variables and altering the ranking system (Simon and Downs 1995). As such, it has been commonly used in altered forms (e.g., Simon and Klimetz 2008; Mukundan et al. 2011; Heeren et al. 2012).

For example, Heeren et al. (2012) applied the channel instability index to streambank reaches in Oklahoma to identify sites in most need of streambank stabilization. Because the index does not consider streambank cohesion and the difficulty in assessing some variables, a modified version was developed called the Oklahoma Ozark streambank erosion potential index (OSEPI). The modified index included variables to consider streambank cohesion and stream curvature. This modified form had high correlation with observed streambank erosion.

Like the OSEPI, assessments have been developed for specific locations. Rinaldi et al. (2013) presented the Morphological Quality Index (MQI) developed to classify stream morphological quantity in Italy. Longitudinal and lateral continuity, channel pattern, cross-sections, bed structure, and the riparian corridor are evaluated in the MQI using 28 variables (e.g., longitudinal continuity in sediment and wood flux, hillslope-river corridor connectivity, structure of channel bed, upstream alteration of flows, vegetation management). The tool was tested on 102 Italian rivers and provides a framework for prioritizing management strategies.

The abovementioned assessment tools have been used to evaluate channel stability. In this work, we extend the assessment tools to evaluate shoreline stability at Alpine Lake, a small (0.6 km^2), man-made lake, in West Virginia. Like streambank retreat, shoreline retreat is a complex process that results from a combination of mass failure, subaerial processes, water level fluctuations, overland flow, groundwater processes, and wave action. The factors vary in importance, depending on reservoir characteristics (Lawson 1985).

Shoreline retreat can result in property damage (Gabriel 2004), and there is concern about shoreline processes at Alpine Lake affecting infrastructure. Alpine Lake has many residential and recreational uses (e.g., fishing, boating, swimming, hiking, cross-country skiing, golfing). The lake is essential for the recreational activities at Alpine Lake resort; however, shoreline erosion is beginning to affect infrastructure critical to recreation, and there is a desire to stabilize the shoreline. We developed a rapid stability assessment tool to apply to the shoreline, compared the assessment results to observed erosion rates, and discuss potential reclamation strategies.

Methods

A rapid stability assessment was developed for Alpine Lake and applied to the shoreline. Erosion was monitored using erosion pins to evaluate the assessment tool.

Alpine Lake Watershed Description

Alpine Lake Resort is a planned community in Preston County, WV, USA on approximately 2,000 wooded acres (8.1 km^2) (Figure 1). A 0.6 km^2 man-made lake is the focus of the community. Amenities include an 18-hole golf course, beach, boating, cross-country skiing, fishing, and lodge (restaurant, pool, and conference center). Boating is allowed on the lake, but no gas-powered engines are permitted (Alpine Lake Resort 2016). There have been few changes in infrastructure to the area in the last 20 years.

The Alpine Lake watershed (4.85 km^2) has a total of streams length of 6.9 km. Most of the developed area includes single-family homes, many of which are only seasonally inhabited, and the infrastructure to support the development. The impervious areas in the watershed (<5% by area) are primarily located in close proximity to the lake and are mainly attributed to roads and houses. In the southern portion of the watershed, the two largest areas of impervious surfaces are due to the Alpine Lake Resort Lodge and a clubhouse associated with the resort (Figures 1 and 2). Forested areas (85% by area) and grassed lawns (7% by area) make up most of the watershed. Approximately 60% of the watershed is underlined by Dekalb soil series. The topography is relatively mild with elevations ranging from approximately 366 m to 975 m above mean sea level (Figure 2). The annual average precipitation is 1.4 m and is relatively evenly distributed with a drier summer/fall season. The water elevation is relatively stable throughout the year but decreases during the dry season. Mean monthly temperatures range from -2.7°C to 20.3°C (NRCC 2016).

Rapid Stability Assessment

A rapid stability assessment tool was developed to assess erosion hazard levels along the lake shoreline (= 4.39 km). The assessment was based on methods by Simon and Downs (1995), Guthrie

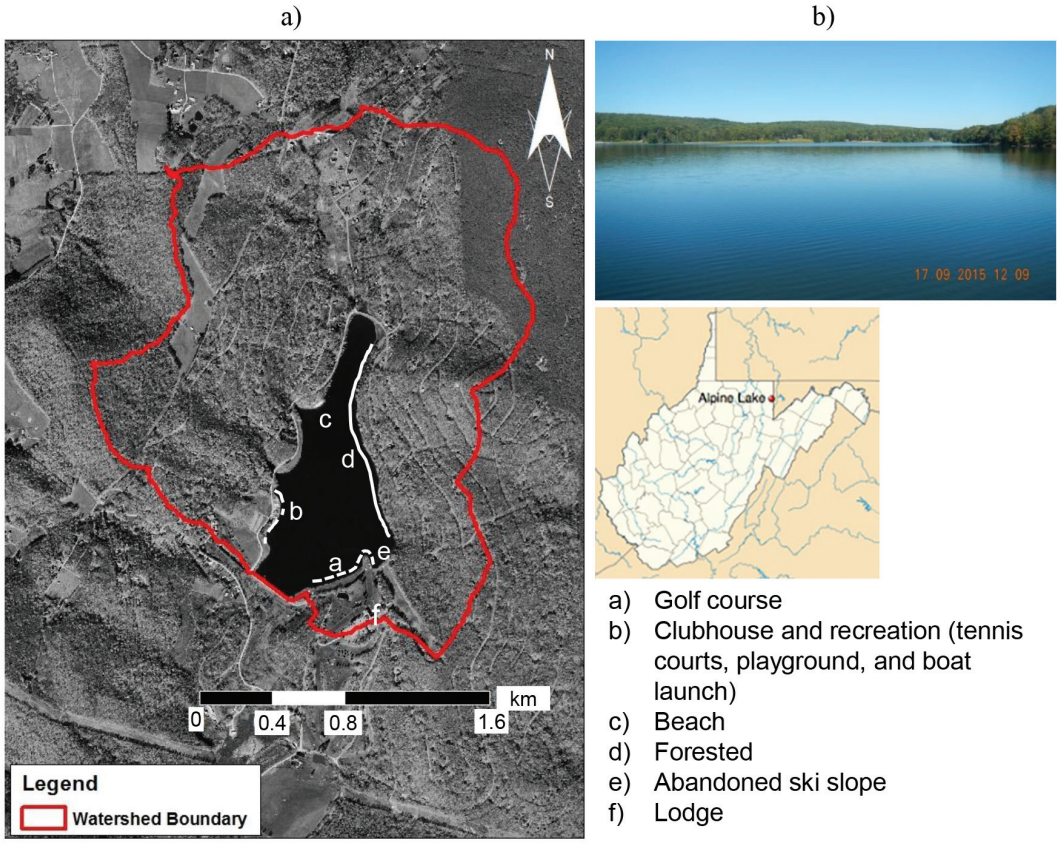

Figure 1. a) Alpine Lake watershed showing major amenities, and b) Alpine Lake located in Preston County, WV, USA.

and Law (2005), Simon and Klimetz (2008), and Heeren et al. (2012). After several field visits, the following metrics were identified as necessary to include in the assessment: 1) bank height, 2) exposed bank length, 3) bank angle, 4) evidence of mass wasting, 5) armoring, 6) wind and wave action, 7) unconsolidated material, 8) shoreline protection, 9) vegetation, and 10) accretion. Table 1 describes the metrics and notes any necessary field measurements. Like prior assessment tools (i.e., Johnson 2005), the intent was to limit the amount of field measurements to minimize evaluation time and not require extensive training to complete.

Each metric was assigned a score where higher values represented a greater potential of erosion or instability. The aggregate score (maximum score = 85) characterized the overall stability value using the following categories: ≤ 30 = very low; 30.5 - 40 = low; 40.5 - 50 = moderate; 50.5 - 60 = high; and ≥ 60.5 = very high. The final version of the rapid stability assessment is available in the Appendix.

The rapid stability assessment (Appendix) was then applied to the shoreline of Alpine Lake by a team of four people (two groups of two) during one week in August 2015 (August 5-11, 2015); training was provided before work began. The lake perimeter was divided into reaches of 20-100 m in length that had similar characteristics. Each factor was rated, and an overall shoreline erosion/stability rating was assigned to each reach. The results were then mapped using GIS. The earthen dam at the southern end of the lake and the shoreline covered by a clubhouse and man-made beach were not included in the evaluation (Figure 1).

Erosion Monitoring

Erosion was monitored in eight locations to evaluate the rapid stability assessment tool. The locations were selected to represent the range of bank conditions observed around the lake. Erosion pins were installed during September 2015 following methods reported by Staley et al. (2006).

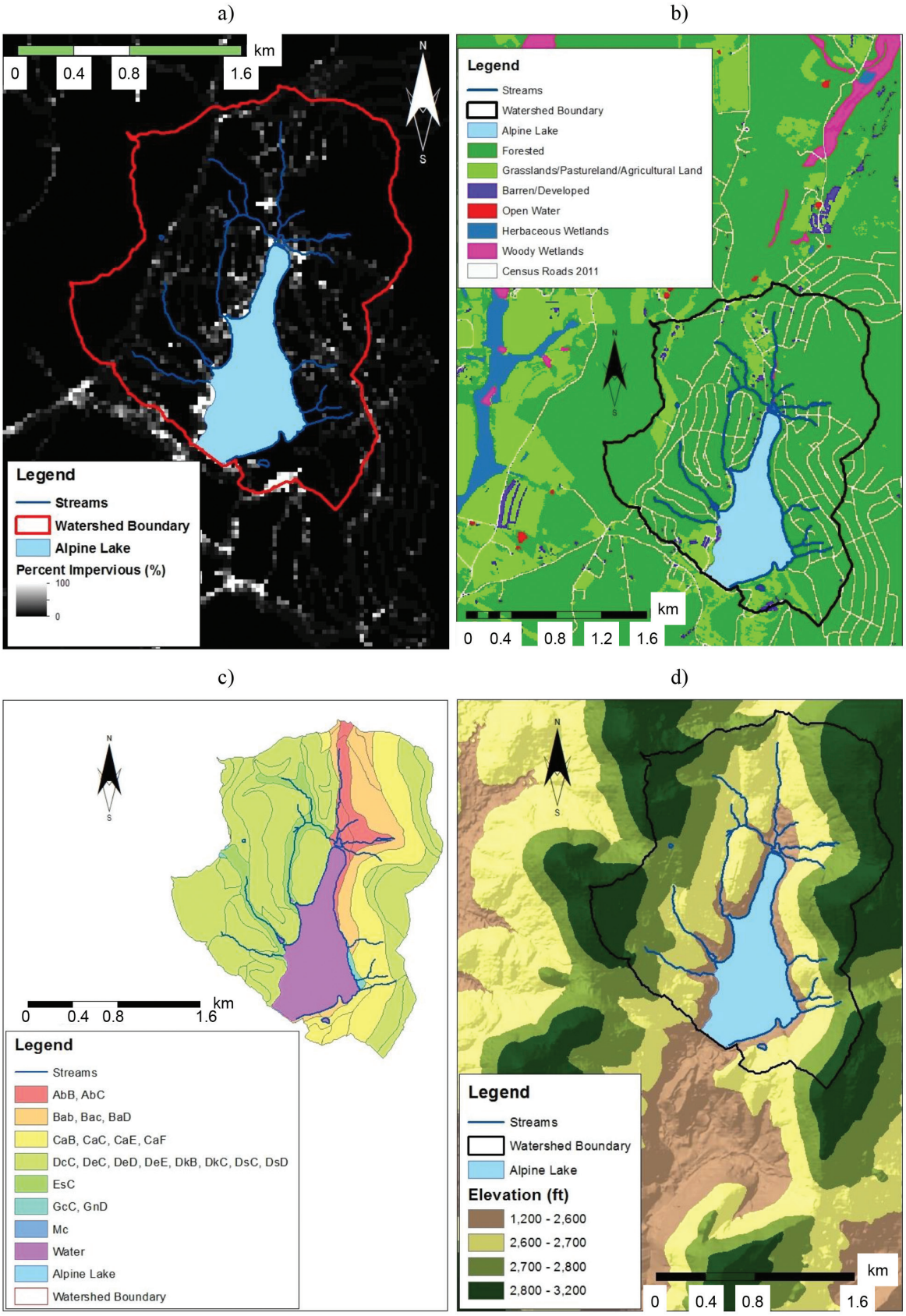

Figure 2. Alpine Lake watershed characteristics: a) impervious surface, b) land use, c) soil type, and d) elevation.

Table 1. Metrics included in rapid stability assessment.

	Description	Equipment
Bank height	Vertical elevation of shoreline	Field tape
Bank angle	Angle of bank measured against the horizontal	Survey equipment or clinometer
Evidence of recent mass wasting/erosion	Observed characteristics of mass wasting (e.g., slough banks, overhanging banks, exposed roots)	*
Evidence of armoring	Coarse gravel or larger particles (D50>16 mm) protecting bank toe	Gravelometer
Wind and wave action	Observed wind direction and wave strength	Compass
Unconsolidated materials	Texture of bank sediment	*Feel method (Soil Survey Staff 2014)
Shoreline protection	Existing protection measures, man-made or natural (e.g., riprap, vegetation)	*
Vegetation contributing to instability	Large vegetation adding weight to bank	*
Occurrence of accretion	Evidence of sediment settling near toe	*

*Field tape needed to determine percent of shoreline affected.

The pins were made of unpolished steel rods (4.8-mm in diameter, 30.5-cm long) and positioned perpendicular to the bank with an initial exposed distance of 3-8 cm. The exposed distance was greater in areas where vegetation was dense so that the pins could be located. The exposed portion of the pins was marked with orange paint. Because the bank height varied among locations, the spacing between erosion pins was not constant and varied from 30 to 70 cm. Locations 1, 2, 3, 4, 5, 6, 7, and 8 had 4, 4, 6, 8, 8, 6, 6, and 5 pins, respectively. The number of pins in the vertical direction ranged from one to three depending on bank height. The number of pins in the horizontal direction varied from two to four (Figure 3). Exposed length was measured once before winter (October 2015) and quarterly beginning in spring 2016 (March, June, and September) with a total monitoring period of one year. The protocol suggested by Staley et al. (2006) was followed and the pins were re-set as necessary during measurements. Erosion rates were calculated for each monitoring period.

Results

Rapid Stability Assessment

The rapid stability assessment was applied to 83 reaches along the shoreline. Stability scores ranged from 17.5 to 62.5. The majority of the locations were considered to have low to moderate potential for erosion (89%). Ten percent of the locations were considered to have high potential for erosion, and one location was identified as having very high potential for erosion (Figures 4 and 5).

There was little variability in the score for the metrics of unconsolidated material, vegetation instability, and accretion (Figure 6). The bank material was primarily cohesive sediment; therefore, more than 75% of the locations had a minimum score for unconsolidated material. Locations with high scores for unconsolidated material were primarily located near the boathouse and beach on the west side of the lake. More than 75% of the locations also had the minimum score

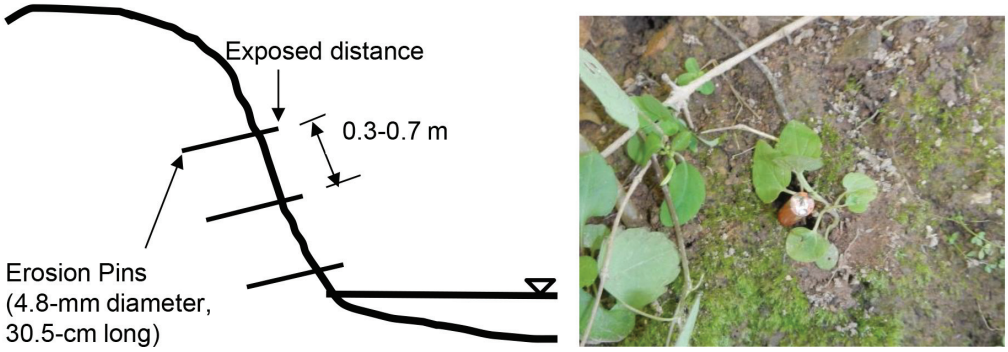

Figure 3. General erosion pin placement with a picture of the exposed erosion pin colored orange.

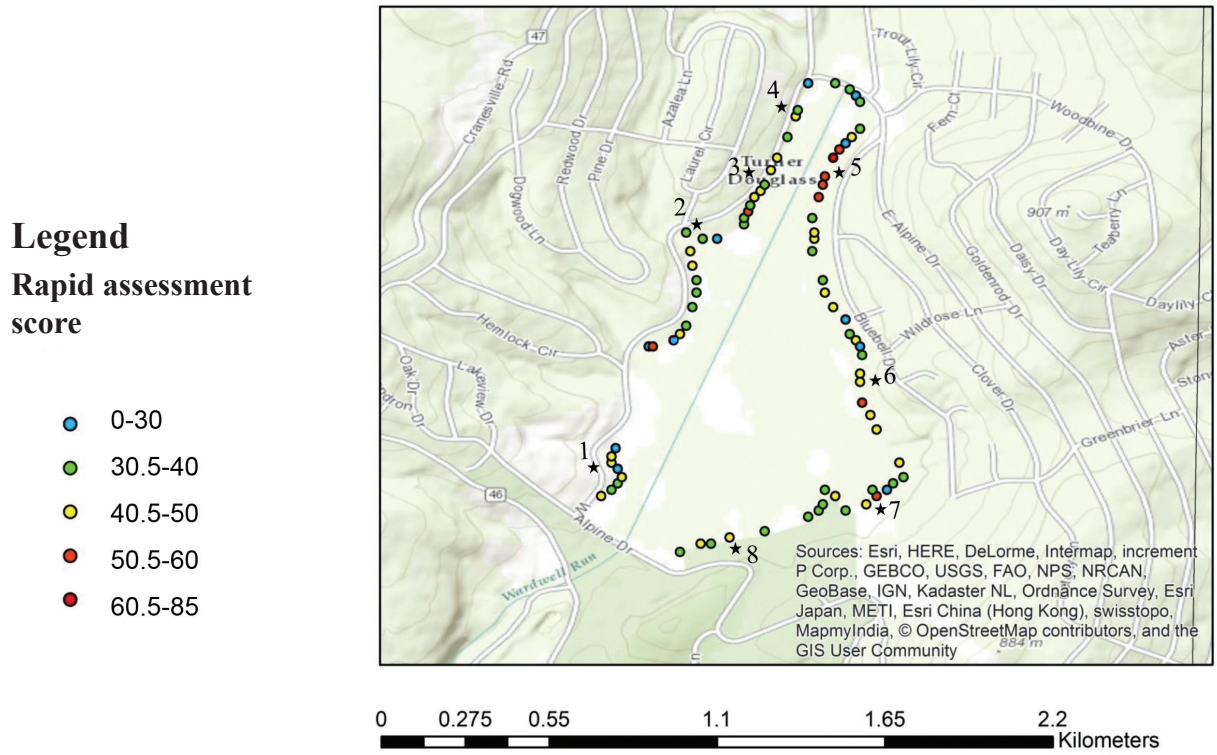

Figure 4. Spatial distribution of overall stability score resulting from rapid stability assessment; stars note erosion pin monitoring locations.

for vegetation adding to instability. The entire west portion of the lake had grass and shrub vegetation that did not contribute to instability. Some trees along the shoreline on the eastern, forested side of the lake had leaning trees along the water's edge. These sites were rated as having high potential for instability shown in Figure 4. Depositing sediment was only observed at a few locations, mainly near the man-made beach, so most locations received the maximum score for the accretion metric (Figure 6).

Bank stability, bank angle, evidence of mass wasting, wind and wave action, armoring, and shoreline protection had more variability in assigned scores. Most of the banks were nearly vertical; some were overhanging which led to a high score. Evidence of mass wasting was observed at varying degrees around the lake. It

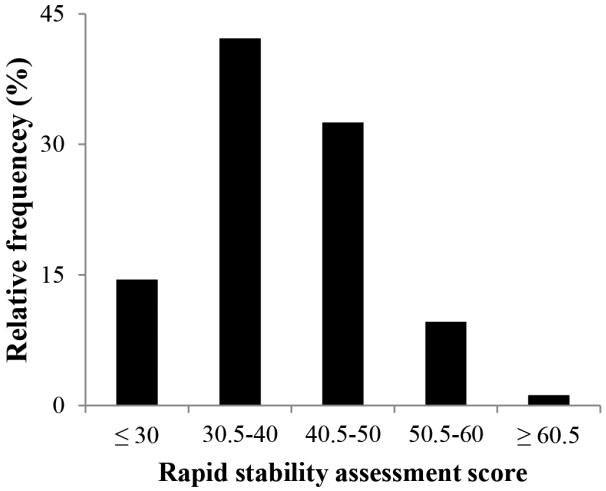

Figure 5. Overall stability score divided by stability classifications; ≤ 30 = very low; 30.5 - 40 = low; 40.5 - 50 = moderate; 50.5 - 60 = high; ≥ 60.5 = very high.

existed in the short, grass-line banks, in the taller banks with shrubs, and along the forested banks. High scores of wind and wave action were located near the boathouse on the west side of the lake and near the protruding land mass in the south portion of the lake. Armoring was evident primarily along the forested portion of the shoreline but existed in locations around the lake.

Measured Erosion

Measured erosion was primarily observed at locations 1, 3, 7, and 8. Negative erosion rates were observed at locations 2, 3, 4, 5, 6, and 7 (Figure 7). These negative erosion rates denote that the erosion pins were partially covered during the monitoring period and represent aggradation. At most locations, localized mass wasting events were the cause of the negative rates. Sediment present at the bank toe was observed at location 2 during the 3/11-6/21 monitoring period. The deposited sediment resulted from a large mass wasting event. This location had a short bank (< 0.5 m), and the entire bank experienced a mass failure event. The mass wasting may have continued but the pins were missing during the final data collection. This site is a common fishing location, and the pins were likely removed by recreation users. The heavy foot traffic in this area also contributes to the mass wasting events, a category not considered in the rapid geomorphic assessment tool.

Discussion

Comparison of Rapid Stability Assessments and Erosion Pins

Both rapid stability assessments and erosion monitoring were needed to assess the stability of the shoreline. The placement of the erosion pins potentially overestimated the erosion rates because the measurements were localized into a few-meter section. Four to eight erosion pins were used to characterize the erosion rates of a 5-10 m reach. The rapid stability assessments were used to assess 20-100 m reaches. The rapid assessments were helpful in identifying overall instability features of the reaches; common contributions to instability were identified to similar reaches around the lake perimeter. The erosion pins showed whether erosion or aggradation occurred in point locations and provided long-term information.

The erosion pins at locations 1 and 2 were both located on the west side of the lake. Both locations had short shoreline bank heights (< 0.5 m) and grass along the shoreline that is mowed frequently (< 15 cm in height observed). There is no natural, un-mowed buffer in either location. Location 2 is near a man-made beach, a common fishing location, and adjacent to a reach lined with riprap.

Low to moderate stability was expected at locations 1 and 2 based on the rapid stability assessments (rapid stability assessment score ≤ 50, Figure 4). On average, the erosion rates at location 1 were low (≤ 0.04 mm/d). This rate could likely be reduced by allowing for a natural vegetation buffer near the water surface. During March to June, large mass failure events occurred at location 2, resulting in the large negative erosion rate value (mean erosion rate = -0.52 mm/d, Figure 7). This large rate was the maximum absolute rate observed. While the bank height here is small, the shoreline is actively adjusting. Riprap is placed on the shoreline near location 2 which is effective in reducing erosion at that site. Fishing and human traffic in this location were unaccounted for in the assessment and should be considered in the future.

Similarly, low to moderate instability was expected at locations 3 and 4 based on the stability assessment (Figure 4). Erosion pins in these locations were positioned on similar banks with large bank heights (> 2 m), natural dense shrub

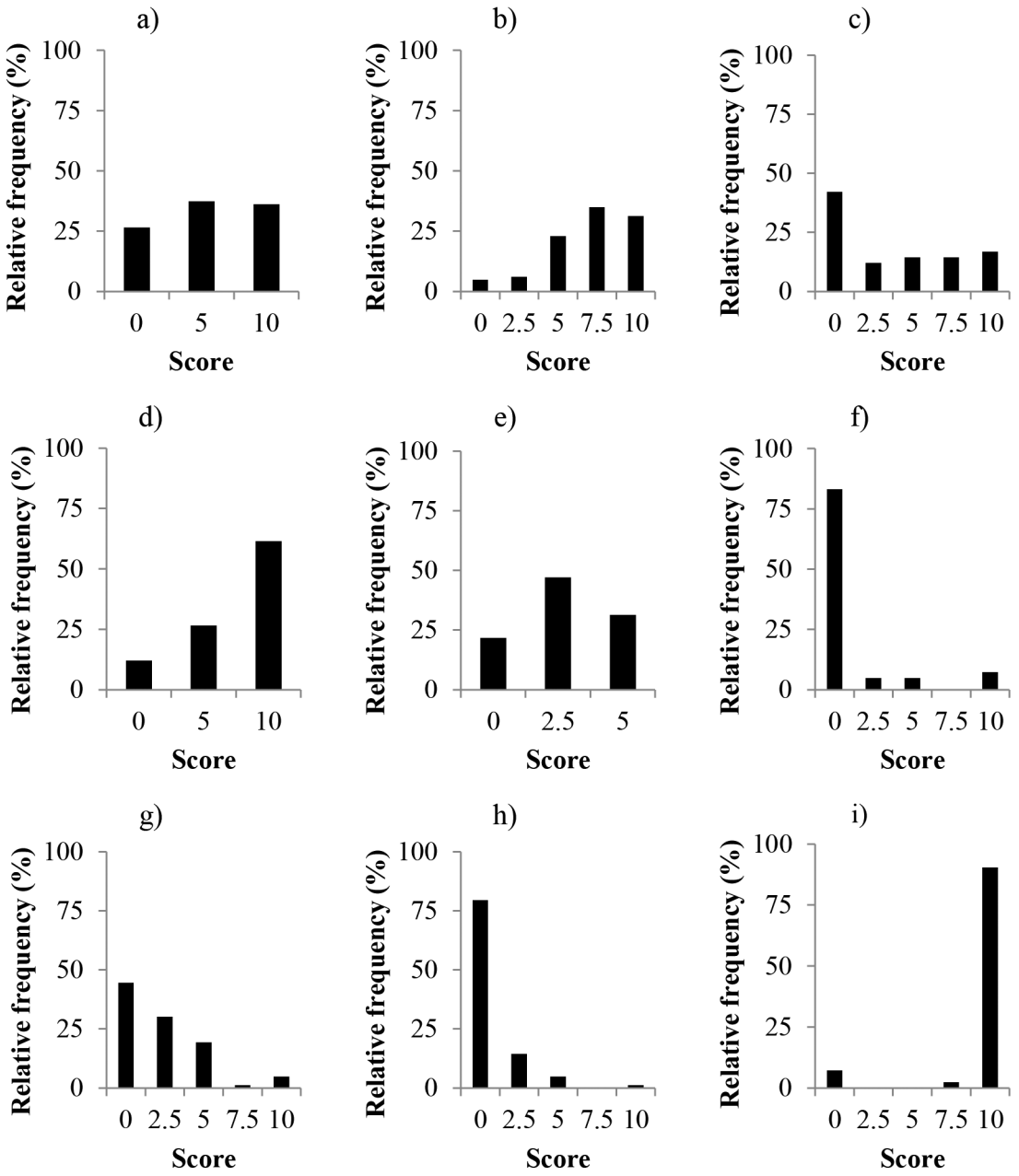

Figure 6. Distribution of score for the metrics in the rapid stability assessment: a) bank height, b) bank angle, c) evidence of mass wasting, d) evidence of armoring, e) wind and wave action, f) unconsolidated material, g) evidence of shoreline protection, h) vegetation contributing to instability, and i) evidence of accretion.

vegetation, and a road near the bank. On average, low erosion rates were observed at location 3 (≤ 0.5 mm/d, Figure 7). The erosion pins spanned the entire bank height at this location and provided a good overall picture of the erosion of the bank; the rapid stability assessment represented the low degree of instability well.

The erosion rates at location 4 were greater than location 3 (mean erosion rate = -0.17-0.11 mm/d, Figure 7), but the pins were not positioned in an area that represented the entire bank. We targeted the placement of the erosion pins near the water surface as we expected the upper part of the bank to be stable; therefore, while the erosion rates

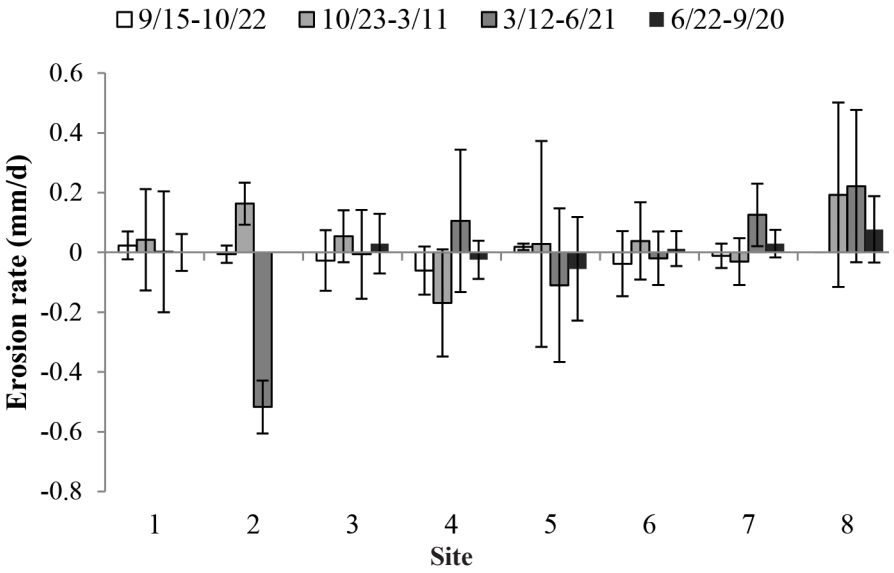

Figure 7. Mean erosion rates for each monitoring period; error bars show standard deviation. (No data for site 2 during 6/22-9/22; pins removed).

measured at this location indicated high instability, the rates were likely overestimated.

Locations 5 and 6 were positioned along the forested east side of the lake. The rapid stability assessments suggest moderate to high instability in these regions. On average the erosion rates in these locations ranged from -0.11 to 0.04 mm/d. However, the variability in erosion rates was among the greatest of all the locations (Figure 7). The trees provide stability, but there was substantial localized erosion around large vegetation (exposed roots, stems, etc.).

Location 7 was at the downslope of a ski slope that is no longer in use. There are areas of erosion especially around drain features (as indicated by the single "high" instability reach in Figure 4). Substantial erosion rates occurred in this location during the wet period (0.12 mm/d) likely due to the runoff from the ski slope (Figure 7).

The final set of erosion pins (location 8) were on a tall (> 1 m) bank adjacent to a golf course. Moderate instability was expected here based on the stability assessment (Figure 4). Vegetation existed on the bank surface at the time of rapid assessment, but there was little vegetation when the erosion measurements were taken during the spring and summer. No erosion was recorded during the first measurement period, but the highest erosion rates and variability in erosion rates were measured in this location during October to June (mean erosion rate = 0.19-0.22 mm/d, Figure 7). The bank is stable during summer months when the water recedes and allows vegetation to establish on the bank. High erosion rates occurred when the bank was bare of vegetation, indicating that multiple assessments may be needed.

Observed Instability Features and Recommendations

Common features of instability were observed around the lake. The lake can be divided into five regions with the following recommended reclamation approaches (Figure 8):

1. *Southwest*: The shoreline in the southwest area of the lake was primarily characterized with low banks (< 0.5 m) and grass vegetation. The grass was frequently mowed to a short height (< 15 cm) all the way to the shoreline. Exposed near-vertical or overhanging bank faces were common, and both fluvial entrainment and mass wasting were observed.

   The impact of shoreline vegetation on bank retreat is complex. Herbaceous vegetation, like that observed in the southwest section of Alpine Lake, absorbs rainfall impact, increases roughness,

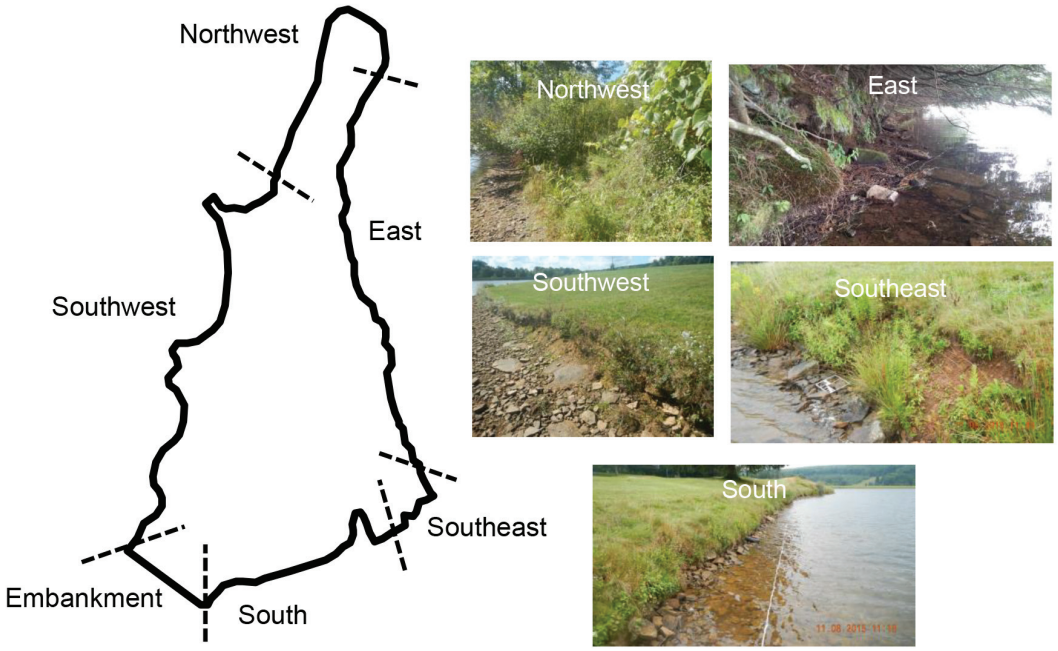

Figure 8. Representative shoreline pictures for each area with common characteristics: southwest, northwest, east, southeast, and south.

influences bank soil temperature and moisture content, and provides root strength through reinforcement (Thorne 1998; Mamo and Bubenzer 2001a, 2001b; Wynn and Mostaghimi 2006). While the vegetation in this location added root strength through reinforcement (Mamo and Bubenzer 2001a, 2001b), roots of herbaceous vegetation only reinforce the top 30 cm or less (Wynn et al. 2004). Further, the low mowing height can lead to reduced root length and increased dead root length (Liu and Huang 2002), limiting root reinforcement benefits.

The stability of this portion of the shoreline could be improved by allowing a vegetation buffer to establish along the shoreline. By reducing the mowing frequency and mowing to a greater height, a greater benefit from shoreline vegetation will be achieved. Active approaches like riprap or vegetation plantings may be needed in the locations near recreation locations (e.g., common fishing locations) where vegetation is less likely to naturally establish in the absence of mowing.

2. *Northwest*: The shoreline in the northwest area of the lake was primarily characterized by high banks (> 2 m) with herbaceous vegetation. Some trees exist but it is not considered forested. A road is in close proximity to the shoreline through this region. The herbaceous vegetation on the bank surface is natural and not mowed and there was little exposed soil during the time of rapid assessment data collection. Compared to areas with exposed soil, vegetated areas have less erodibility, more shear strength, and lower detachment rates (Mamo and Bubenzer 2001a, 2001b). The vegetation absorbs rainfall impact, provides resistance, moderates temperature fluctuations, alters the bank moisture content, and adds root reinforcement (Thorne 1998; Mamo and Bubenzer 2001a, 2001b; Wynn and Mostaghimi 2006).

Because the vegetation along this bank is dense and varied in species, additional plantings would not likely promote greater stability. Observed erosion rates in this region were low (locations 3-4, Figure 7)

so no reclamation strategy is likely needed unless the road is undermined by shoreline adjustment.

3. *East:* The shoreline ground surface elevation increased gradually. This feature is consistent with forested stream systems; forested streams are typically wider than grassed channels and slower to erode than grass-lined channels (Zimmerman et al. 1967; Davies-Colley 1997; Trimble 1997; Allmendinger et al. 2005). Localized fluvial entrainment around exposed roots and woody vegetation was observed, but measured erosion rates were low. A large buffer region exists between the shoreline and community infrastructure. Based on the rapid stability assessment and erosion measurements, there are no recommendations for reclamation in this region.
4. *Southeast:* The shoreline in the southeastern portion of the lake is between the forested section and the area adjacent to the golf course. The banks are generally tall (> 1 m), and runoff from a former ski slope likely contributes to fluvial entrainment of the bank. Because there is more area for reclamation without interfering with community infrastructure, a series of plantings and a reduction of the shoreline angle would be appropriate for this location.
5. *South*: The banks on the southern region of the lake were tall (>1 m), had exposed bank material, and are adjacent to the community golf course. Fluvial entrainment of the exposed bank material as well as localized mass wasting during wet months was observed. Because the adjacent land is a golf course, the full benefit of the grass vegetation is not attained as it is maintained at a low height (Liu and Huang 2002). An active approach to reclamation like riprap is likely needed because the banks have little room to adjust before impacting the infrastructure (i.e., golf course). Reducing the bank angle and planting vegetation would encroach on land used for golfing greens.

Substantial erosion rates were observed in this location even though the stability assessment indicated that the banks were relatively stable (Figures 4 and 7). This inconsistent result highlights the need of multiple assessment techniques to adequately characterize shoreline stability. The rapid stability assessment was completed during the fall in a stable period; no erosion was recorded following the rapid stability assessment, but continued erosion monitoring showed the continued bank adjustment (Figure 7).

Conclusion

A rapid stability assessment tool was developed to evaluate the stability of the shoreline of Alpine Lake. Assessment categories included bank height, exposed bank length, bank angle, evidence of mass wasting, armoring, wind and wave action, unconsolidated material, shoreline protection, vegetation, and accretion. The tool identified locations at risk for instability as well as determined common attributes to consider for designing management efforts. Some limitations were identified and are summarized hereafter:

- The rapid stability assessment was developed over the summer months. The data collection for the rapid assessment of the entire shoreline was completed within one week during August, the driest time of year. The rapid assessment tool was evaluated using erosion measurements collected over a one-year period. The vegetation was fully established on the shoreline bank face in some locations during the rapid assessment data collection where it does not exist during other times of the year. Some reaches, especially near the golf course, were rated as having low to moderate potential for instability with the assessment tool. Later in the year, high erosion rates were observed at some of these locations. Therefore, if the rapid assessment tool is used alone, it should be repeated during the year to confirm the aggregate score and ratings.

- Additional categories may be needed in future versions of the Alpine Lake Rapid Stability Assessment Tool. The current version did not account for the impact of human activity on the bank stability. Mass failures partly caused by foot traffic were observed at popular fishing locations. Recreation activities should be considered in the future.

In summary, the rapid stability assessment tool proved to be an effective tool for identifying the means by which the banks are adjusting, identifying commonalities around the lake, and prioritizing future management techniques. In the absence of erosion pin monitoring, multiple rapid assessments during different seasons would be useful to best quantify the erosion potential. Like previous riverine assessment tools, it could be modified for larger lakes by adding and removing categories.

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Appendix: Rapid Stability Assessment Field Form (Figures Al and A2)

Alpine Lake, Rapid Stability Assessment Field Form (1/2) **SCORE:** _____

I. Personnel			
Date:	**Time begin:**	**Time end:**	**Name(s) of crew:**
Weather:		**Rain in the last two days?** □ Yes □ No	**Photo number range:**

II. LOCATION

Site Name: _____

GPS waypoint #:_____ **GPS name:** Garmin etrex 20 **GPS datum: (e.g. NAD 83)** WGS 1984

UTM field reading: Longitude_____**Latitude**_____**GPS Error: ±** 49.213 ft

Elevation:_____ (ft)

Length of Reach: _____ (ft)

Water Depth: _____ (ft) (representative of reach)

Representative Reach photo: □ Yes **Photo Number(s):**_____

III. PHYSICAL ASSESSMENT

Bank Height:_____ (ft)

< 1.6 ft (low)	1.6-3.3 ft (moderate)	> 3.3 ft (high)	(circle one)
0	***5***	***10***	***(Score, circle one)***

Exposed Bank Face Length:_____ (ft)

Bank Angle:

0-20°	21-60°	61-80°	81-90°	>90°	(circle one)
0	***2.5***	5	***7.5***	***10***	***(Score, circle one)***

Evidence of Recent Mass Wasting/Erosion (Percentage of Shoreline):

0-10%	11-25%	26-50%	51-75%	76-100%	(circle one)
0	***2.5***	5	***7.5***	***10***	***(Score, circle one)***

Gullies?: □ Yes □ No Number:_____; Average width: _____ (ft); Average depth: _____(ft)

Mass wasting/Erosion?: □ Yes □ No

Number of locations:_____; Average width: _____ (ft); Length of shoreline affected:_____ (ft)

Picture of Erosion: □ Yes □ No (Take pictures of significant failure/erosion)

Picture Number(s)	**Description(s)**

Evidence of Armoring (Big particles at toe, low transport):

High	Medium	Low	(circle one)	Average rock size: _____
0	***5***	***10***	***(Score, circle one)***	

Figure A1. Rapid stability assessment field form, page 1.

Alpine Lake, Rapid Stability Assessment Field Form (2/2) **SCORE:** _____

Wind and wave action

// to wind direction, low action	45° to wind direction	90° to wind direction; high action	(circle one)
0	***2.5***	***5***	***(Score, circle one)***

Unconsolidated Material (Percentage of Shoreline)

0-10%	11-25%	26-50%	51-75%	76-100%	(circle one)
0	***2.5***	5	***7.5***	***10***	***(Score, circle one)***

Shoreline Protection (Percentage of shoreline covered by plant roots, vegetation, downed logs, branches, rocks, etc.)

0-10%	11-25%	26-50%	51-75%	76-100%	(circle one)
10	***7.5***	5	***2.5***	***0***	***(Score, circle one)***

Description of protection:

Picture of protection: □ Yes □ No (Take pictures of representative vegetation if not captured in reach photo)

Picture Number(s)	**Description(s)**

Vegetation Contributing to Instability (Percentage of shoreline covered by trees leaning at shoreline)

0-10%	11-25%	26-50%	51-75%	76-100%	(circle one)
0	***2.5***	5	***7.5***	***10***	***(Score, circle one)***

Number of trees: _____

Picture of Trees: □ Yes □ No

Picture Number(s)	**Description(s)**

Occurrence of Accretion (Percentage of shoreline with deposition)

0-10%	11-25%	26-50%	51-75%	76-100%	(circle one)
10	***7.5***	***5***	***2.5***	***0***	***(Score, circle one)***

Notes:

Total Score_____

Hazard Class:

0-30 points	**30.5-40 points**	**40.5-50 points**	**50.5-60 points**	**60.5-85 points**
Very Low	**Low**	**Moderate**	**High**	**Very High**

Good candidate for erosion monitoring? (Circle one based on field experience)

YES NO

Why yes?

Figure A2. Rapid stability assessment field form, page 2.

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